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Computerizing Bird Collections and Sharing Collection Data Openly: Why Bother?

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Abstract. Natural history museum collections provide the basic documentation of life on Earth. As such, they represent the critical and unique resource by which that life may be understood, and have immense economic and scientific importance. Nevertheless, particularly in recent decades, natural history museums have seen less and less attention – and resources – in spite of their importance. A series of new efforts, however, aim to recoup that prominence via community efforts to unite data resources towards a vastly improved understanding of biodiversity and its implications. The Species Analyst represents an effort to unite natural history collections databases worldwide to this end: 77 institutions now cooperate or are committed to cooperate in serving records of 51 million natural history museum specimens to users worldwide, and has seen more than 700,000 users to date.

Key words. The Species Analyst, TSA, archive for biodiversity, worldwide facilities

1. INTRODUCTION

Computerization of ornithological collections is increasingly considered a priority for curators and staff of natural history museums. A common quandary, however, is how and why to get started. The curator is presented with a bewildering variety of databasing programs, some especially designed for specimen records, and others off-the-shelf generic database programs that can be customized for any use. Choice of a platform, choice of data fields, and choice of computerization strategy all become critical – and difficult – consideration. Unfortunately, these considerations can often seem so complex that computerization efforts are not initiated.

Moreover, presented with a thousand and one other priorities of collections building, specimen conservation, institutional politics, and research efforts, and given the significant time investment that computerization requires, the question arises as to whether the result is worth the time. That is, one must consider what are the benefits of computerization, and how much do they benefit the collection, the curator, and the broader community.

The purpose of this contribution is to provide a rationale for computerizing bird collections as a critical step forward in their care. Along the way, we review steps involved – a sort of minimum-standard guide to starting computerization efforts. Finally, we provide a series of examples of how computerizing collections data, and sharing those data across many institutions worldwide, benefits the collections themselves.

2. WHY COMPUTERIZE A COLLECTION?

Databasing or computerizing a collection is a lot of work, and may easily absorb years of effort. So why do it? Several reasons argue strongly for taking this step. A partial list follows:

- *Get to know your collection* – a sweep through the whole collection, drawer by drawer, gives a unique knowledge of a particular collection.
- *Discover important specimens* – many fascinating discoveries have resulted from the specimen-by-specimen attention during computerization efforts, including species new to science, lost type specimens, important historical specimens, etc.
- *Detect problems* – again, the specimen-by-specimen attention can help to detect serious problems that might otherwise not be noticed … damage from insects or water, fading of plumages, drying of spirit specimens, etc.
- *New views of the collection* – although we are familiar with summaries of collections in terms of taxonomic completeness, and perhaps regional summaries, many new views of collections open when a collection is computerized, e.g., maps of the geographic distribution of specimens, summaries of accessions over time, etc.
- *Save curatorial time* – making summaries of holdings, preparing loan invoices, tracking down particular specimens, and many other curatorial tasks are considerably more efficient when the collection is available in database form.
- *Standardize taxonomy* – once data are in electronic form, comparing names against a standard list (e.g., the Peters' check-list) can identify a first set of non-

standard names that require checking and updating.
- *Efficient information access* – many questions and data requests that require hours or days of work for an uncomputerized collection will suddenly become feasible to answer in minutes, making possible much more creative uses of the information in collections. For example,
  - What are your holdings of taxon X?
  - What are your holdings from country X?
  - Do you have specimens collected by person X?
  - What is the history of specimen acquisition rates in your collection?
  - And many more …

In short, computerization of a collection is a major undertaking, but ends up repaying the investment of time and effort many times over.

3. CHOOSING A PLATFORM

The first big question to be answered is about which platform (databasing program) to use. This decision becomes complex … sometimes, museum administrators decide to force all collections in the museum to use the same program. Even if one has the freedom to choose, should one choose among the many programs that have been developed specifically for natural history museum specimens (BIOTA, BIOTICA, SPECIFY, etc.), or a generic program off the shelf (e.g., Microsoft Access, Oracle)? Regarding this choice, each option has its strengths and weaknesses (Table 1). In general, we would recommend the off-the-shelf option for small, old, or inactive collections, and the specimen databasing programs for larger, data-rich, and very active collections.

Regardless of this choice, one should insist on several minimum criteria for a databasing platform. These criteria are critical features of a program that must be fulfilled in order to avoid problems. As follows:

- Capacity for export to other, generic formats, particularly ASCII delimited format, to allow reporting, export to other programs, and porting to future technologies and platforms.
- Compatible with Standardized Query Language (SQL), which permits many functionalities to be added to your database related to sharing data.

Once a platform has been identified that fits the particular needs of a collection, and meets these basic requirements, then design of the computerization effort can begin.

If the reasoning outlined above suggests that the best solution to computerization is that of a more complex program specifically designed for natural history specimen data, then you should read about several of the programs that are available. Links to a number of such programs are presented in Table 2.

Table 1: Summary of advantages and disadvantages of specialized versus generic programs as platforms for computerizing bird collections.

NATURAL HISTORY MUSEUM SPECIMEN DATABASING PROGRAMS	OFF-THE-SHELF GENERIC DATABASING PROGRAMS
Advantages Designed specifically for specimen management Features such as authority lists, loan invoice reporting, etc. No customization or little customization required Most complex solutions specific to natural history specimens are tractable	Long-term continuity of support from the company Easy availability of expert advice, given broad usage in many communities Simplest solutions are feasible Simple learning curve
Disadvantages Can disappear – long-term support often depends on a person – researcher or developer – who can decide not to support the program further, or who may decide not to update to newer versions (e.g., MUSE) Expert advice may be unavailable in a particular city May not permit very simple solutions to simple problems Steeper learning curve	May need customization of program for intermediate-to-complex situations Not designed specifically for specimen data Complex features (e.g., reporting, authority lists) not automatically available

Table 2: Selected specialized programs designed specifically for collections data. Provided are World Wide Web links for more information.

Program	URL
SPECIFY	http://usobi.org/specify/
Biótica	http://www.conabio.gob.mx/biotica _ingles/distribucion_b. html
BioLink	http://www.biolink.csiro.au/
BIOTA	http://viceroy.eeb.uconn.edu/biota
KE EMu (not recommended for integration via *Species Analyst*)	http://www.kesoftware.com/

4. CHOOSING DATA FIELDS

This step may prove to be the most critical of all in the process of computerization. With too many fields, time and filespace are wasted, whereas with too few, they will have to be added later or one will have to live without them. If an incorrect structure is chosen, the database may be forever handicapped by this design flaw. However, the challenge is reduced quite a bit with an understanding of a few basic ideas. Specimen data, in their simplest form, distill down to three linked sets of information about each specimen:

– *Taxonomic information* – the taxonomic identity of the specimen
– *Geographic information* – the geographic location of its collection
– *Detailed documentation of the specimen* – time of collection, collector identity, museum catalogue number, sex, age, body mass, etc.

Thinking in this manner, we can envision a structure for a specimen database that would capture this information optimally. Taxonomy and geography are both hierarchical concepts, and so we can represent them as such, which would make for three interacting sets of information (Fig. 1).

In the simplest sense, then, even in a spreadsheet program such as Microsoft Excel, or (better still) as a single table in a database program such as Microsoft Access, one could use a straightforward single table that holds critical fields (see Table 3). This very simple structure provides a clear, workable solution for small collections. In a more complex situation, in which more specimens are to be computerized, this structure can be made relational (Fig. 1) (that is, made up of several tables that interconnect). The advantage of a relational database structure is that elements of the database are entered only once: e.g., the locality descriptor for the 150 specimens collected at USA/ Kansas/Douglas Co./Lawrence/10 km E is entered only once, reducing the possibility of typographical errors.

Table 3: Critical minimum set of fields for a simple collections database.

Field	Example
Catalogue number	15230
Genus	Cyanocitta
Species	cristata
Subspecies	cristata
Date of collection	24 October 1956
Collector	Fredrick E. Jones
Sex	Female
Age	Adult
Body mass	120 g
Country	USA
State or province	Ohio
County	Butler Co.
Named place and directions from	Oxford, 10 km E

This sort of simple relational structure can be implemented in a program such as Microsoft Access with a few hours' attention by a technician familiar with the program. The custom specimen database programs use a more complex relational structure, but one that is in essence based on this overall backbone. Again, the more complex the demands that one will wish to place on the database (e.g., more complex queries, more detailed reporting, more specimens), the more complex the database structure that will be required. For relatively simple applications, however, the simple flat file (single table) setup described above will often be adequate.

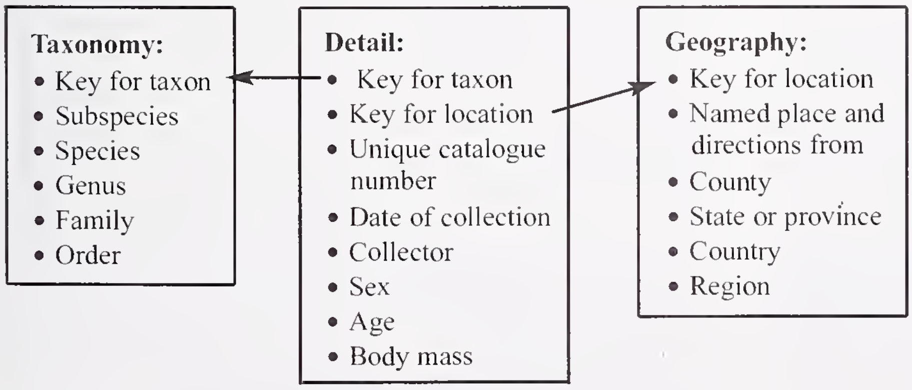

Fig. 1: Diagrammatic illustration of a simple relational database structure designed to link hierarchically organized geographic and taxonomic information with specific data regarding a particular specimen.

5. COMPUTERIZATION STRATEGY

The next question to be faced is the strategy for computerization. This decision depends heavily on the exact situation of a collection. If, on the one hand, an excellent paper catalogue or card file exists, one may wish to computerize directly from that, and then verify the accuracy and completeness later from the actual specimens. If, on the other hand, a good card file or catalogue does not exist, or if many specimens may have been omitted (exchanged or deaccessioned) or not entered in the catalogue, then you may be better off computerizing directly from specimens.

In general, two passes through the collection will be necessary as part of any computerization effort. The first will simply get each specimen's data into the computer as efficiently as possible. The second will verify (1) the existence of the specimen, (2) that all data elements are entered in the database, and (3) that all of the specimen's data are correct as entered. This verification step, although labor-intensive, is critical to making the database a correct representation of the information contained in the specimens' labels.

All computerization efforts should involve the critical step of backing up data at regular intervals. Too many 'impossible accidents' have removed a year of work, and set a computerization effort back terribly. Backing up data should be done as permanently as possible … that is, compact disks are better than floppy disks. It should also be done with redundancy: each time that you make a copy, if at all possible, it should not over-write the previous copy. This preservation of 'versions' of the database allows one to go back a week or a month if some error appears in the data set. Finally, given the possibility of more catastrophic losses, the back-up copies should be stored off-site, preferably in several places. Excellent storage sites for these copies can include libraries or archives, or curators' homes, or they can even be transferred via the Internet or via mail to another country.

6. THE SPECIES ANALYST (TSA)

The Species Analyst (http://speciesanalyst.net/) is a collection of software tools that permits integration of computerized collections data among institutions around the world into a distributed biodiversity information facility. For example, a user might wish to ask for records of any taxon from Yellowstone National Park or from Burma, or all specimens collected by Alexander von Humboldt, and retrieve information in a matter of seconds from 50 institutions around the world.

TSA uses a hybrid of Z39.50 (an information transfer protocol developed about 20 years ago in the bibliographic community) and XML (a more modern and efficient protocol) to permit efficient query and retrieval of data. TSA may be accessed via a web portal that permits basic queries, or via extensions to Microsoft Excel (for retrieval of data in spreadsheet format) and ArcView (for retrieval of data as GIS coverages) (downloads available at http://speciesanalyst.net/downloads).

TSA currently integrates data sets from 22 institutions, for a total of 15 million specimen data records for over 50,000 species; a total of 58 institutions has committed to participation formally, which will take the total number of specimen records served to about 50 million. A special strength at present is in ichthyological data, as FishNet (http://speciesanalyst.net/fishnet/) has taken excellent advantage of TSA technology to create a data facility linking most important computerized fish collections. Now funded is a parallel network for mammal collections data (MANIS, based at the Museum of Vertebrate Zoology; http://elib.cs.berkeley.edu/manis/), and networks for herpetological and ornithological (expanded) specimen data are pending and in preparation, respectively.

7. WHY SHARE DATA ONCE COMPUTERIZED?

Above, we listed the first set of benefits of computerization of bird collections – namely, freer and more complete access to the information content of the specimens that make up the collection. These benefits are indeed considerable, and add enormously to a curator's ability to take care of a collection. However, once data are computerized, if they are shared, and integrated with data from other collections around the world, an additional set of benefits accrues.

In essence, a set of emergent properties comes into being once all (or nearly all) data are integrated for a particular taxon or region. We have come to appreciate these emergent properties as we have assembled the Atlas of Mexican Bird Distributions (Navarro & Peterson, in prep.), a centralized database now including the contents of more than 60 natural history museum collections of Mexican birds. This 11-year project has resulted in a diversity of synthetic publications regarding the Mexican avifauna (Navarro-Siguenza et al. 1992a, b; Peterson 1993; Peterson et al. 1993; Peterson 1998; Peterson et al. 1998a, b; Navarro-Siguenza & Peterson 1999, 2000; Peterson et al. 2000, 2001, 2002). Herein, we will use this exemplar data set to demonstrate a variety of potential benefits to broad integration of data across institutions, as follows:

7.1 Georeferencing as a Community

Georeferencing locality data for specimens opens doors to a multitude of new capabilities and new func-

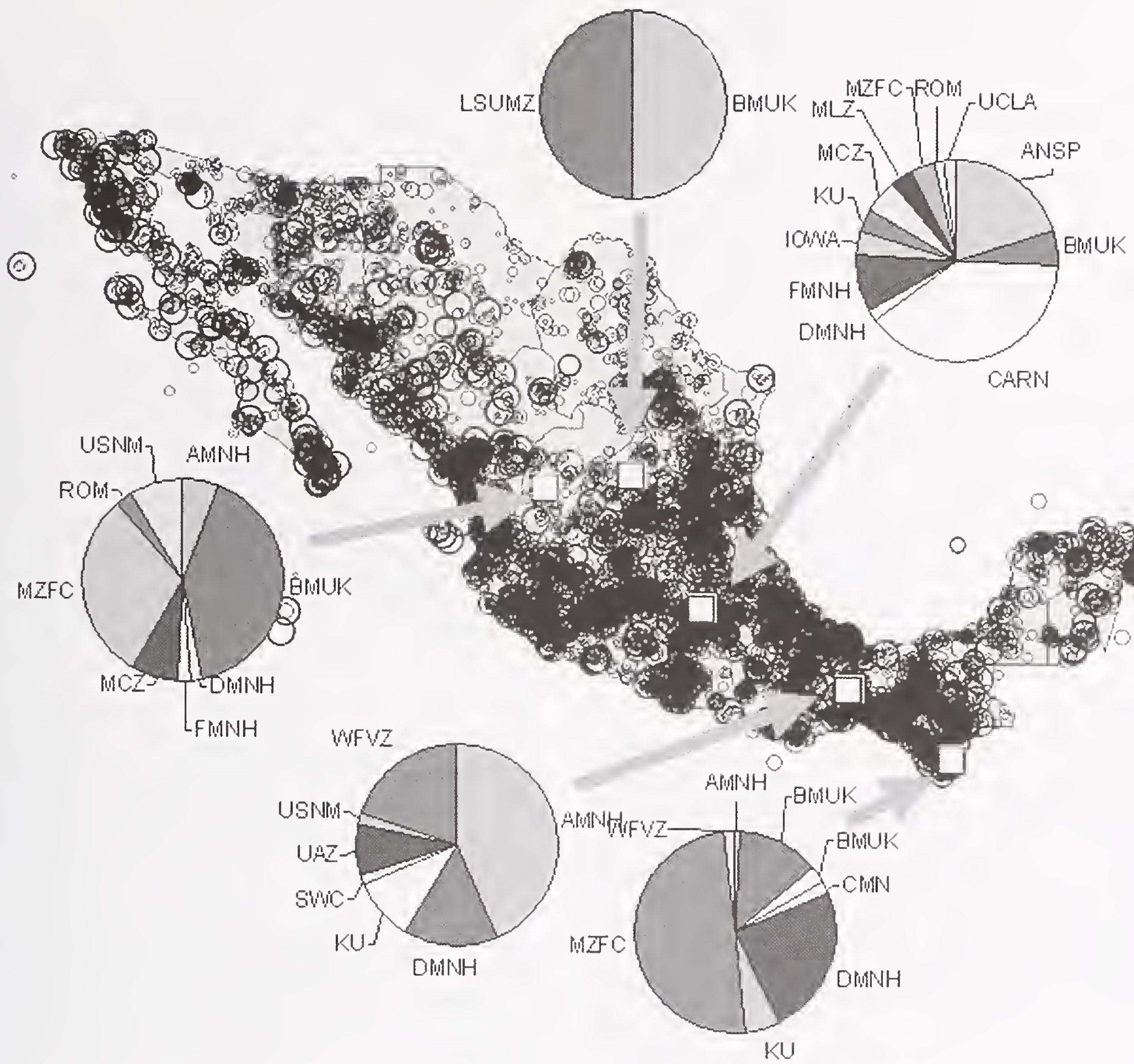

Fig. 2: Map of Mexico with collecting localities plotted by numbers of specimens collected at each point (graded symbol size: smallest = 1 specimen, largest = >100 specimens). For five points, to illustrate the redundancy of collecting localities among museums, we provide pie diagrams that illustrate the relative holdings of specimens from that particular site among scientific collections (see Acknowledgements for institutions and abbreviations).

tionalities to collections data. Indeed, all of the advances of geographic information systems (GIS) open up to collections data once latitude and longitude data are available for the collecting localities for each specimen. Nevertheless, georeferencing collections data – even once they are in electronic form – represents an enormous task.

Integrating this task over many institutions, however, takes advantage not just of having more people to help in a large task, but also of the redundant nature of the geographic sampling of birds (Fig. 2). Indeed, more than 25 % of Mexican bird collecting localities occur in more than one museum, and some in more than 20 museums. This redundancy results from collections being dispersed among numerous museums (e.g., the specimens of Wilmot W. Brown from Chilpancingo, Guerrero), and from certain sites being especially accessible or well-known as collecting localities in particular regions (e.g., Cerro San Felipe, Oaxaca).

A first experiment in cooperative georeferencing is beginning in the mammal community in the United States. The MANIS network, a U.S. National Science Foundation-funded effort, is connecting 17 institutions with computerized holdings of mammal specimens. A first step in MANIS' integration efforts is the pooling of institutional lists of localities to be georeferenced; institutions are then 'signing up' for particu-

lar regions, perhaps a home state, or an area of particular interest to the curator. In this way, efforts in georeferencing have a direct return for a particular investigator or institution, and add to the community pool of georeferenced information.

7.2 Detecting Errors in Date and Locality

Once specimen data are integrated, and have been georeferenced, further data refinements are possible. A common question is that of the relative reliability of the data associated with specimens from different collectors (BINFORD 1989). Because of the fragmented and dispersed nature of collector's material it has always been out of reach before. For instance, the still-living collector and ornithologist Robert W. DICKERMAN has deposited specimens at 14 of the 32 museums included in our present summary; the early twentieth century collector Wilmot W. BROWN has specimens distributed across 23 of the 32 museums. Once these data are pooled, however, new insights become possible regarding collectors' relative reliability.

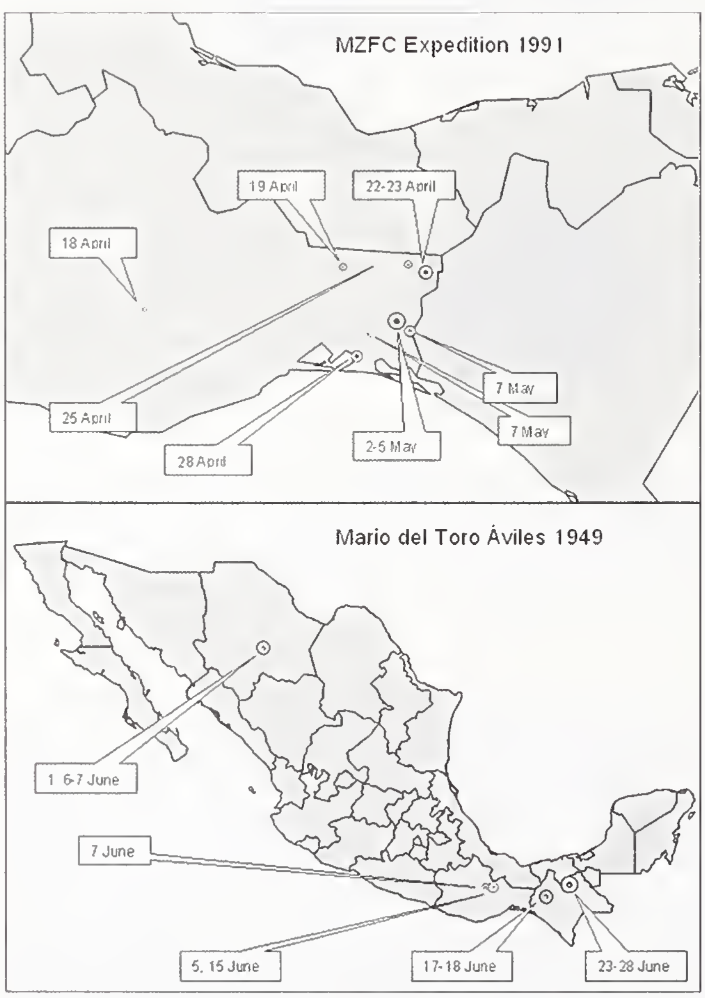

Fig. 3: Maps of collecting localities for two contrasting groups of collectors in Mexico: a Museo de Zoología, UNAM (MZFC) expedition in Spring 1991, and the collections of Mario del Toro Áviles in June 1949. Organized by collections date, consistencics and inconsistencies of specimen labeling become clear.

Basically, by assembling the entire opus of a collector, and sorting specimen locality by collecting date, it is possible to assess how geographically reasonable the combination of dates and localities is. Hence, to present a contrasting pair of examples, a Museo de Zoología, UNAM, expedition in 1991 scouted numerous sites in central and eastern Oaxaca (Fig. 3, top); although its route was complex, specimens from particular localities were clumped in time, and a sensible route could be reconstructed (although, in constructing this example, we detected an error in our georeferencing … the 'Benito Juárez' referred to in the locality descriptor was the one in eastern Oaxaca, not the one in central Oaxaca). In stark contrast, specimens scattered across four museums (MLZ, LACM, FMNH, USNM) suggest that the infamous collector Mario del TORO ÁVILES worked at several sites across Mexico in June 1949; plotting these localities by date, however, reveals a number of points at which impossibly long journeys would have had to have been made in too short a time (Fig. 3, bottom). This result confirms earlier suspicions that del TORO ÁVILES' dates and localities are to be regarded with utmost caution (BINFORD 1989; PETERSON & NIETO-MONTES DE OCA 1996).

This approach can be used to detect problems in collectors' series, which will either be errors in date of collection or in collecting locality. Indeed, for an integrated, distributed data set consisting of the holdings of many institutions, it could be implemented as an error-seeking module that scans the data set collector by collector, and flags particular records as potential problems. These flagged specimen lists could then be distributed to collection curators for checking.

7.3 Detecting Errors in Identification or Georeferencing

A further refinement to specimen data also becomes possible, which will detect problems either in species identification or in georeferencing of localities. In essence, by viewing large quantities of occurrence data for a particular species, it is possible to detect spatial outliers, which likely represent identification or georeferencing problems. This process can be refined still further via ecological niche modeling for species: the ecological needs of a species are modeled (PETERSON 2001; PETERSON et al., in press) using high-end computational tools (STOCKWELL & NOBLE 1992; STOCKWELL 1999; STOCKWELL & PETERS 1999). These procedures use known occurrences of a species to produce a geographic view of areas meeting and not meeting its ecological needs; overlaying the same known occurrence points used to build the models allows identification of outlier occurrences.

As an example of this approach, we used the known occurrences of the brush-finch *Atlapetes pileatus* to

Fig. 4: Map of known collecting localities for the brush-finch *Atlapetes pileata*, overlain on a map of regions fitting the modeled ecological needs of the species (in gray), showing an old coastal locality in Tamaulipas as falling outside of the species' ecological niche.

build an ecological model and identify areas of appropriate and inappropriate ecological conditions for the species (Fig. 4). The modeling algorithm used is detailed elsewhere (STOCKWELL & NOBLE 1992; STOCKWELL 1999; STOCKWELL & PETERS 1999; PETERSON 2001; PETERSON et al., in press), but the result is that all known occurrence points fall into areas predicted to be appropriate for the species except one. This point (Fig. 4) represents an old locality on the coast of Tamaulipas, in the lowlands of eastern Mexico. The ecological modeling procedure identifies this site as a specimen locality that is not within the ecological possibilities of the species, and most likely represents an erroneous locality designation.

Like the collector itinerary approach, a procedure based on ecological niche modeling could be implemented as an error detection facility. A computer could periodically scan the pooled data resources for known occurrence points of each species, build ecological niche models for each species, and detect occurrence points that fall outside the ecological limits of the species. These points can then be flagged for checking by curators or collections staff.

7.4 Community-wide Activities: The Power of Numbers

Much more generally than for the preceding examples, it is important to emphasize the power of working of a community. When a proposal stems from a Division of Mammalogy at a particular museum, it carries far less force than a proposal that comes from all of the Mammalogy divisions from 17 institutions. This power of numbers – working as a community – makes possible many bold new funding initiatives.

Indeed, in the Species Analyst effort, several such community proposals have already been prepared, and have proven enormously successful. Proposals have been prepared and funded for a pilot North American bird network (U.S. National Science Foundation, funded 1998), a 15-member fish data network (U.S. National Science Foundation and U.S. Office of Naval Research, funded 2000), and a 17-member mammal data network (U.S. National Science Foundation, funded 2001). This success clearly results from the community nature of the proposals, and has resulted in more than $2 million of new funding being available to the systematics collections community.

More generally, community efforts constitute an important step towards demonstrating the power of the systematics collections community in many real-world challenges. Work as a community shows the true analytical power of the data that the systematics collections community holds. This power is a key in convincing funding agencies, museum administrators, and decision-makers in general of the importance of systematic collections.

8. CONCLUSIONS

The point of this piece is that computerization is not a prohibitively difficult or expensive endeavor; rather, it is an important step in curating a collection that more than pays for itself in (1) saving time and effort in curatorial activities, (2) improving data quality and removing erroneous elements, and (3) improved funding possibilities and recognition by administrators and decision-makers. Most important is to make some simple decisions, start into the task, and methodically carry it out.

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ences, Canadian Museums of Nature, Denver Museum of Natural History, Delaware Museum of Natural History, Fort Hays State University, Field Museum of Natural History, Iowa State University, University of Kansas Natural History Museum, Los Angeles County Museum of Natural History, Naturhistorisches Museum (Vienna), Louisiana State University Museum of Natural Science, Museum of Comparative Zoology (Harvard University), Moore Laboratory of Zoology (Occidental College), Museum Nationale D'histoire Naturelle (Paris), Museum of Vertebrate Zoology (Berkeley), Museo de Zoología (Facultad de Ciencias, UNAM), University of Nebraska, Royal Ontario Museum, San Diego Natural History Museum, Texas Cooperative Wildlife Collections, University of Arizona, University of British Columbia Museum of Zoology, University of California at Los Angeles, Universidad Michoacana San Nicolás de Hidalgo, United States National Museum of Natural History, Western Foundation of Vertebrate Zoology, and Yale Peabody Museum.

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